Form ESA-B4. Summary Report for ESA-189-03
Public Report - Final

Company	United States Steel Corporation	**ESA Dates**	October 7-9, 2008
Plant	Gary Works	**ESA Type**	Fan Systems
Product	Steel	**ESA Specialist**	Mr. Michael Kostrzewa, P.E.

Brief Narrative Summary Report for the Energy Savings Assessment:

Introduction:
This integrated steel making plant consists of both steelmaking and finishing operations, employs 6,500 people, and is situated on approximately 3,000 acres on the south shore of Lake Michigan. Sheet products, hot strip mill plate products, and tin products are manufactured at the plant. Hot rolled, cold rolled, and galvanized sheet products are produced for customers in the automotive, metal building components, home construction and appliance markets. The plant also produces electrolytic tinplate and black plate tin mill products used in the manufacture of food and beverage containers, aerosol cans, paint cans and pails. The plant has an annual raw steelmaking capability of 7.5 million tons. The plant also operates three coke batteries, with annual production capacity of 1.6 million tons.

Significant operations and equipment at the plant includes the following:

- Four blast furnaces
- Three top-blown (BOP) steelmaking furnaces
- Three bottom-blown (Q-BOP) steelmaking furnaces
- Vacuum degasser
- Four continuous casting lines
- Ladle metallurgy facility
- 84-inch hot strip mill
- Six-stand, five-stand and two-stand cold reduction lines
- 84-inch and 80-inch pickle lines
- Hot rolled temper mill
- Hot rolled coil prep line
- Electrolytic Cleaning line
- Continuous annealing line
- Three batch annealing facilities
- Two temper mills
- 80" recoiler
- Hot dip galvanizing line
- Electrogalvanizing line
- Two electrolytic tinning lines

Objective of ESA:
The objective of the ESA was to identify potential energy savings opportunities related to fan systems while introducing facility personnel to the U.S. Department of Energy's Fan System Assessment Tool (FSAT).

Focus of Assessment:
The primary focus of the ESA was on significantly large, constantly running fans throughout the production operations that did not already have adjustable speed drives installed.

Approach for ESA:

1. A preliminary list of fans, motor sizes, typical electric loads, run hours, drive type, and flow controls was provided by plant staff in advance of the ESA.

2. A training session was conducted for plant staff to introduce the concepts of fan optimization and the Fan System Assessment Tool.
3. The Energy Expert, Site Lead, and other plant personnel brainstormed for fans with potential for analysis.
4. A general tour of the facility and the production operations was conducted by the Site Lead and the Energy Expert. During this tour, large fans and fans with production significance were identified and briefly examined.
5. Motor and fan performance and nameplate information was collected by the Energy Expert and the plant personnel.
6. Fan system optimization analyses were conducted by the Energy Expert and plant personnel.
7. A training session was conducted for plant staff to introduce the concepts of fan optimization and the Fan System Assessment Tool.
8. A debrief presentation detailing the process and the opportunities developed during the ESA was presented to the Site Lead.

General Observations of Potential Opportunities:
From preliminary information supplied by the plant, the energy consumption and costs from all sources is given in the table below:

	Consumption	Unit Cost	Total Fuel Cost
Total Natural Gas Consumption	24,372,100 MMBtu		
Total Electricity Consumption	1,382,100,000 kWh 4,717,000 MMBtu		
Total Light Fuel Oil Consumption	3,111,000 MMBtu		
Total Heavy Fuel Oil Consumption	286,000 MMBtu		
Total Coal Consumption	19,799,000 MMBtu		
Total Other Gas Consumption	28,375,000 MMBtu	This fuel is generated onsite	
Total Other Liquid Consumption	1,977,000 MMBtu	This fuel is generated onsite	
Total Other Solid Consumption	60,001,000 MMBtu	This fuel is generated onsite	
TOTAL ENERGY CONSUMPTION	**142.638 TBtu**		

The following Near Term, Medium Term, and Long Term Opportunities were identified during the ESA:

1. <u>Open Damper and Install a VFD to Reduce the Flow on #1 Q-BOP Gas Cleaner Fans (Long Term Opportunity)</u>
   The #1 Q-BOP Gas Cleaner process has two large Louis Allis Type WPIIS induced draft fans direct driven by 8,500 hp, 13,800 volt, 1,180 rpm induction motors. These fans pull gases from the blast furnaces at 2.6" w.c. through a control damper, a series of water baths, and through a set of dampers at the inlet of each fan before discharging to atmosphere. The control damper is set to 75" w.c. and the pressure into the fan inlet damper is typically 87" w.c. But each fan is rated at about 300,000 cfm, so the inlet dampers are usually set at about 50% to reduce the flow. During the site visit, the flow through the North fan was at about 90,000 acfm air at about 72ºF. The power consumption at these conditions is about 6,500 kW. On an annual basis, this translates to about 56,940 MWh/yr and about $2,847,000/yr per fan.

   Measuring ports were not available during the site visit to measure the pressure drop across the damper. But a reasonable estimate is that the drop across the damper is about 10" w.c. Thus, the estimated damper efficiency is 10 ÷ 87 = 11.5%. The energy lost through the damper is proportional to the damper efficiency × motor power (electric) or 11.5% × 6,500 kW = 747.5 kW. Assuming that the damper is closed continuously for 8,760 h/yr, the annual electric energy attributed to this damper at 50% closed is 747.5 kW × 8,760 h/yr = 6,548,100 kWh/yr and the annual energy cost for this damper is 6,548,100 kWh/yr × $0.050/kWh = $327,400/yr. Allowing for both fans, the total annual electric energy attributed to these dampers 13,096,200 kWh/yr and the annual energy cost for these dampers is $654,800/yr

The typical solution for a fan with a closed inlet fan damper would be to reduce the speed of the fan to achieve the desired flow and open the damper to eliminate the unnecessary drop across the damper. This can typically be accomplished in one of four ways: 1) install a motor with a slower rated speed (or rewind an existing motor); 2) install a two-speed motor in place of the existing motor; 3) install a new synchronous motor; or 4) install an adjustable speed drive. A manufacturer of large drives was consulted to see it is feasible to install an adjustable speed drive for this application. Drives are available and depending upon the motor type, a load commutated inverter (LCI) drive might be appropriate if it is a synchronous motor. From discussion with the vendor, a budget cost for an appropriate drive is about $2 million per drive or about $4 million total, with a more specific number available from further investigation. The simple payback for this installation would be about 6.1 years.

This opportunity will need to be validated with the actual pressure drop across the damper and motor/fan nameplate and performance specifics (if available) before specific implementation options can be developed. As such, this is considered to be a long term opportunity.

2. <u>Reduce Flow on #2 Q-BOP PM10 Baghouse When Idle (Near Term Opportunity)</u>
The #2 Q-BOP PM10 Baghouse has two Robinson dual inlet radial tip fans (74.75" diameter x 38" width). Each fan is direct driven by a two-speed Westinghouse Electric 1,750/250 hp, 4,160 volt, 196 amp, 1,188/395 rpm induction motor. Each fan is rated at 290,000 acfm at a fan static pressure of 21" w.c. (based on a gas temperature of 275ºF and a density of 0.0579 lb/cf). Each fan has an inlet and outlet damper. The inlet dampers are controlled to maintain a fan motor current.

At present, the fans operate such that only one fan runs at a time and the fan runs with full open dampers. But the fans were originally configured so that the both fans could operate at high speed or low speed with either one or two fans operating to match fan output flow to production demands. Operating at two-speeds numerous times led to a catastrophic failure of the fan blades on Fan #2, so new fans have been ordered and one has been installed. When the second fan is installed, the fan operation can be changed again to match the production demands.

Typically, the furnace operates at a level of 30 charges per day, with a peak of about 55 charges per day. During the charge, the fan needs to operate on high flow (speed) to provide sufficient airflow to the operation. Allowing for 5-10 minutes per charge, this translates to about 240 minutes per day. But for the remainder of the time, the fans could operate at the lower flow (speed) or about 1,440 min/day – 240 min/day = 1,200 min/day or about 83% of the day. Currently, the fans operate at about 165 amps at full load continuously. Using FSAT, the estimated power at high speed and 165 amps is 956 kW. From previous experience, plant personnel determined that the fans operate at about 400 rpm and 55 amps. Using FSAT, the estimated power at low speed and 55 amps is 150 kW. The estimated savings would be (956 – 150 kW) = 806 kW for 83% of the day or 806 kW × 83% × 24 h/day × 365 day/yr = 5,883,800 kWh/yr. Using an impact cost of $0.05/kWh, the annual cost savings would be 5,883,800 kWh/yr × $0.05/kWh = $294,200/yr.

Since a new fan is ordered, implementation will not require any additional capital costs. There will be some changes needed in programming the controllers and environmental regulations require that another compliance test will be required under the proposed operating scenario. Allowing for a cost of $50,000 for these items, the simple payback would be about 0.2 years.

Given that the new fans should be installed soon, this is considered to be a near term opportunity.

3. <u>Install VFDs on #2 Q-BOP Cooling Tower Fans (Medium Term Opportunity)</u>
The two cooling towers serve the #2 Q-BOP processes each contain two axial fans that are driven by two-speed motors that are rated at 175 hp on high speed and 40 hp on low speed. At present, the fans operate in the two-speed mode. Using typical weather data from Chicago (TMY3 data for ORD), the average wet-bulb temperature is 44.8ºF and the maximum wet-bulb is 80.4ºF. *If the process cooling load were constant throughout the year,* both fans in a tower should be able to run at the low speed below the average wet-bulb temperature. For the range between the average and maximum wet-bulb, the fans would run on high-speed in proportion to how close the wet-bulb temperature is compared to the maximum wet-bulb. From preliminary calculations for a constant load, the average energy consumption in this mode would be about 2,022,000 kWh/yr or about 1,701,000 kWh/yr × $0.050/kWh = $85,000/yr. The energy consumption and cost if the fans ran at full-speed for a constant load throughout the year would be 2,300,000 kWh/yr and $115,000/yr, so this already represents a significant savings. Additional savings would result from installing variable frequency drives on the fans. For a constant cooling load and assuming the that fans would operate at about 32% of full load below the average wet-bulb temperature and ramp up in flow similar to the two-speed fan operation (allowing that fan performance laws show that the power

varies as the cube of the flow), the estimated energy consumption would be about 854,000 kWh/yr per tower, or a savings of 1,701,000 kWh/yr - 854,000 kWh/yr = 847,000 kWh/yr and $42,350/yr per tower. Plant personnel estimate that the cost to retrofit each tower with VFDs and appropriate controls would be about $150,000, resulting in a simple payback period of about 3.5 years.

Additional analysis will be required to estimate the energy savings under the actual conditions at the plant where the cooling load is not constant throughout the year, but varies with production. Plant personnel are encouraged to work with the tower manufacturer for this analysis as they likely have the analysis tools that can better estimate these savings. Still, the analysis above represents a reasonable estimate of the potential savings.

Given the payback period, this is considered to be a medium term opportunity.

4. <u>Open Damper and Install a VFD to Reduce the Flow on Coke Plant 5 & 7 Baghouse Fan (Long Term Opportunity)</u>
Like the #1 Q-BOP Gas Cleaner fans, the Coke Plant 5 & 7 baghouse fan is always working against a partially closed damper. The induced draft fan is driven by a Siemens Allis 800 hp, 6,900V, 885 rpm motor rated at 66 amps full load. The fan is used to clear exhaust gases from the coke ovens, and the flow varies depending on whether the oven is charging or unloading. When the flow is high, the set point for motor amps is about 61 amps, which corresponds to a damper setting of about 65% open. During low flow periods, the set point is 45 amps, corresponding to a damper setting of about 30% open. Measurements of the actual flow conditions during the ESA indicate that the flow during low flow periods is about 128,200 acfm and a fan static pressure of about 6.5" w.c. From electrical measurements of the fan motors input into FSAT, the total shaft power required to deliver this flow is 494.5 hp and the electric power required is 396 kW. At 61 amps, during high flow, the shaft power is about 731 hp and the electric power required is 583 kW. From process logs on 10/7/2008 from 3:52 a.m. through 11:52 a.m., the fan was in the idle mode for about 55% of the time. *Assuming that this is a reasonable approximation of how the fan operates*, the total annual energy consumption and energy cost during the high flow periods is 583 kW × 8,760 h/yr × 45% = 2,299,800 kWh/yr and $115,000/yr; during the low flow periods, the total annual energy consumption and energy cost are 396 kW × 8,760 h/yr × 55% = 1,907,900 kWh/yr and $95,400/yr. Thus, the total annual energy consumption and cost are 4,207,700 kWh/yr and $210,400/yr.

Measuring ports were not available during the site visit to measure the pressure drop across the damper. But a reasonable estimate is that the drop across the damper is about 1" w.c. Thus, the estimated damper efficiency is 1 ÷ 6.5 = 15%. The energy lost through the damper is proportional to the damper efficiency × total annual energy consumption or 15% × 4,207,700 kWh/yr = 647,300 kWh/yr and $32,400/yr.

Like the #1 Q-BOP Gas Cleaner fans, this opportunity can be implemented by reducing the speed of the fan to achieve the desired flow and opening the damper to eliminate the unnecessary drop across the damper. At another plant the installed cost of a 1,500 hp, 4,160V drive was about $360,000 or about $240/hp. For a budget cost, a reasonable assumption is that this cost rate is valid for the 800 hp, 6,900 V motor considered, so that a budget implementation cost is 1,500 hp × $240/hp = $192,000. The simple payback for this installation would be about 5.9 years. Another option that might work instead would be to install a two-speed motor in place of the existing motor. It is also important to note that there may be additional savings by considering the idle set point. The motor set point of 45 amps has been determined by experience to allow a quick enough response when high flow is called for – going below this level may sacrifice safety. But with a VFD, the response time should be as quick, if not quicker, so perhaps a lower idle level may be possible.

This opportunity will also need to be validated with the actual pressure drop across the damper before specific implementation options can be developed. As such, this is considered to be a long term opportunity.

The energy savings from these opportunities total about 21,321,300 kWh/yr and $1,066,100/yr. About 28% of identified electricity savings would result from near term opportunities, 8% from medium term opportunities, and 64% from long term opportunities.

Definitions:

- Near term opportunities would include actions that could be taken as improvements in operating practices, maintenance of equipment or relatively low cost actions or equipment purchases.
- Medium term opportunities would require purchase of additional equipment and/or changes in the system. It would be necessary to carryout further engineering and return on investment analysis.
- Long term opportunities would require testing of new technology and confirmation of performance of these technologies under the plant operating conditions with economic justification to meet the corporate investment criteria.

Management Support and Comments:
Plant and corporate engineering personnel are pursuing energy efficiency, operating cost, and safety improvements throughout the site. Energy savings appears to be a priority at multiple levels of site and corporate management and engineering groups. Management and plant personnel were supportive of the ESA and the results derived from the training assessment. Plant personnel will likely use FSAT to assess other energy saving opportunities for this plant and other corporate locations.

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